International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Physical Activity with Type 1 Diabetes: Care and Best Practices

Md Kamran Khan

Nidan Kutir Diabetes Care & Research Centre, Bhagalpur, Bihar, India

Abstract: ***The treatment of type 1 diabetes mellitus (T1DM) depends on three key components: insulin therapy, dietary management, and consistent physical activity. Exercise places metabolic demands on the body, influenced by an individual's energy reserves, fitness level, environmental factors, and the intensity, duration, and type of activity. These elements, combined with potential stress from competitions, affect glucose metabolism. The athletic pursuits of individuals with diabetes are often challenged by risks such as hypoglycemia during or after exercise, frequent hyperglycemia before, during, or after specific activities, the potential for ketoacidosis, and the presence of chronic microvascular or macrovascular complications. Aerobic activities tend to lower blood glucose levels, while anaerobic exercises may cause temporary hyperglycemia. Although people with diabetes can excel in sports, optimizing their physical performance requires meticulous blood glucose monitoring, appropriate adjustments to insulin doses on exercise days, and tailored nutritional strategies. This review explores the effects of physical activity on glucose metabolism, alongside dietary considerations and approaches suited for individuals with T1DM engaging in exercise.***

Keywords: Diabetes Mellitus (T1DM), exercise, physical activity, blood glucose, nutrition therapy

1.Introduction

Type 1 diabetes mellitus (T1DM) is an autoimmune condition characterized by the destruction of pancreatic beta cells, resulting in absolute insulin deficiency. Managing T1DM in the context of athletic pursuits requires a delicate balance of insulin therapy, dietary management, and physical activity to maintain optimal blood glucose levels while minimizing complications such as hypoglycemia, hyperglycemia, and ketoacidosis. Due to its health benefits, exercise is strongly encouraged for diabetic individuals. Many people with T1DM incorporate regular physical activity into their lives, participating in activities ranging from recreational sports and school competitions to elite-level athletics, including Olympic pursuits. These activities are generally safe for T1DM patients, provided that athletes and their healthcare teams carefully address the specific needs and challenges of the condition during exercise. (1, 2)

Athletes with T1DM encounter unique challenges during training and competition, including managing the physiological demands of varying exercise intensities, adjusting meal timing, meeting specialized nutritional needs, and handling competition-related physical stress. Additionally, there is a significant risk of hypoglycemia during and after exercise, as well as frequent occurrences of hyperglycemia before, during, or after certain activities, which can elevate the risk of ketoacidosis. Chronic complications, such as microvascular and macrovascular issues, may also impact the athletic careers of those with T1DM. (3, 4)

Although there is a lack of robust, well-controlled studies on effective treatment plans for diabetic athletes engaging in regular training, this review seeks to evaluate current evidence on the effects of physical exercise on blood glucose regulation, alongside nutritional considerations and practical strategies for safe exercise participation in individuals with T1DM.

This article explores the physiological effects of exercise on glucose metabolism in individuals with T1DM, the unique challenges they face, and evidence-based strategies for optimizing performance through insulin adjustments and nutritional planning.

Effects of Physical Activity on Glucose Metabolism in T1DM

Exercise imposes significant metabolic demands, influenced by the type, intensity, and duration of activity, as well as individual factors such as fitness level and energy reserves. The two primary types of exercise—aerobic and anaerobic—have distinct effects on glucose metabolism in T1DM:

1. Aerobic Exercise: Activities such as running, cycling, or swimming rely on oxidative metabolism, which increases glucose uptake by skeletal muscles, primarily through insulin-independent glucose transporter type 4 (GLUT4) translocation to the cell membrane. This can lead to a rapid decrease in blood glucose levels during and after exercise, increasing the risk of hypoglycemia. Hypoglycemia risk is particularly pronounced during prolonged aerobic activities, especially if insulin doses are not adjusted or carbohydrate intake is inadequate. (5)
2. Anaerobic Exercise: High-intensity, short-duration activities like weightlifting or sprinting rely on glycolysis and can cause a transient increase in blood glucose due to the release of counter-regulatory hormones (e. g., catecholamines, glucagon, and cortisol). These hormones promote glycogenolysis and gluconeogenesis, potentially leading to hyperglycemia during or immediately after exercise. However, post-exercise glucose levels may drop as glycogen stores are replenished. (6)
3. Mixed Activities: Many sports, such as soccer or basketball, combine aerobic and anaerobic components, resulting in unpredictable glucose responses. This variability necessitates real-time monitoring and individualized management strategies. Additional factors, such as competition-related stress, environmental

conditions (e. g., heat or altitude), and the presence of microvascular or macrovascular complications, further complicate glucose regulation. For instance, individuals with diabetic neuropathy may have impaired counter-regulatory responses, increasing hypoglycemia risk. (7)

Physical exercise involves metabolic demands that vary based on the type of exercise (aerobic or anaerobic, depending on the primary energy source used), its form (continuous or intermittent, based on whether exercise sets are uninterrupted), intensity (ranging from very light to maximal), and duration (short, moderate, or long). These demands are also influenced by environmental factors such as temperature, humidity, time of day, and altitude, as well as an individual's energy reserves and fitness level. The effort exerted during exercise can be indirectly assessed through oxygen consumption. The maximum oxygen uptake (VO2 max) per minute reflects the body's peak aerobic capacity. During moderate-intensity exercise (40-59% of VO2 max or 55-69% of maximum heart rate), aerobic metabolism primarily uses carbohydrates and free fatty acids as energy sources. When oxygen demand exceeds 75% of VO2 max, the exercise shifts to anaerobic metabolism. However, even low-intensity exercise can become anaerobic at high altitudes or for individuals who are sedentary, anemic, or have cardiac or pulmonary conditions. (8)

When transitioning from rest to moderate exercise, the body activates sympathetic and hormonal systems, triggering the use of glucose stored in muscles and the liver, as well as the release of free fatty acids from adipose tissue. In nondiabetic individuals, a blood glucose drop of 8 mg/dL or levels around 65-70 mg/dL prompts increased glucagon and epinephrine secretion. Alpha-adrenergic stimulation in the pancreas suppresses insulin release while promoting glucagon secretion, which drives neoglucogenesis and glycogenolysis, boosting glucose production by approximately 5 mg/kg/min. This mechanism helps maintain stable blood glucose levels (80-100 mg/dL) during exercise, countering muscle glucose consumption of about 3 mg/kg/min during moderate activity. In adults with type 1 diabetes mellitus (T1DM), glucose oxidation rates during moderate exercise are around 2 mg/kg/min, and in adolescents with T1DM, about 1.5 mg/kg/min, leading to a rapid decline in blood glucose due to an impaired glucagon counter-regulatory response. In some T1DM patients, glucagon response to low glucose levels may weaken after a few years, though some studies report normal glucagon release during exercise. However, elevated exogenous insulin levels in T1DM can suppress glucagon secretion, either directly or indirectly, and reduce lipolysis and proteolysis, further complicating glucose regulation. (9, 10)

Research by Chokkalingam et al. indicates that during moderate-intensity exercise, fat oxidation contributes 15% of total energy expenditure in T1DM patients on high insulin doses and 23% in those on low doses, compared to about 40% in nondiabetic individuals under similar conditions. Hyperglycemia in T1DM patients further suppresses lipid oxidation during exercise, but when glucose levels are around 97 mg/dL and insulin levels are approximately 122 mmol/L, lipid oxidation rates align with those of nondiabetics. The high carbohydrate oxidation rate in T1DM during exercise may contribute to rapid blood glucose declines. (11, 12)

Several factors influence plasma glucose levels in diabetic athletes, with hypoglycemia potentially occurring immediately after exercise or hours later. During or shortly after moderate-intensity exercise, an inadequate energy intake relative to exercise demands, combined with excessive subcutaneous insulin administration in areas active during exercise, can accelerate insulin absorption and promote hypoglycemia. Exercise also enhances insulin's effects by facilitating glucose transport across cell membranes, increasing muscle glucose uptake by up to 20 times. A single exercise session can boost insulin sensitivity by up to 40% for 48 hours, benefiting glycemic control in both diabetic and nondiabetic individuals but increasing the risk of delayed hypoglycemia in those with T1DM. (13, 14)

Research indicates that the two primary defenses against hypoglycemia are compromised in individuals with type 1 diabetes mellitus (T1DM). These patients cannot effectively reduce circulating insulin levels and exhibit an impaired glucagon response. Consequently, epinephrine serves as the primary counter-regulatory mechanism against hypoglycemia in T1DM, but its response may be weaker and only triggered at very low blood glucose levels. As a result, autonomic symptoms of hypoglycemia are diminished in these individuals. (15, 16)

Symptoms of hypoglycemia driven by adrenergic (sympathomimetic) activation include hunger, tremors, anxiety, rapid heart rate, and palpitations, while neuroglycopenic symptoms, caused by reduced glucose availability for brain function, include weakness, fatigue, poor coordination, slurred speech, and blurred vision. Repeated hypoglycemic episodes can desensitize the body to epinephrine, a condition known as hypoglycemia-associated autonomic failure (HAAF). According to Davis et al., just two hypoglycemic episodes with glucose levels below 70 mg/dL can reduce the counter-regulatory response by 30% in subsequent episodes. (17, 18)

Hypoglycemia remains a significant and concerning challenge for athletes with type 1 diabetes mellitus (T1DM). To optimize performance and safety, athletes with T1DM, or individuals engaging in regular physical training, should aim to maintain blood glucose levels between 120 and 180 mg/dL during exercise. However, many athletes develop a personalized understanding of their optimal glucose range for specific activities through experience and monitoring. (19)

Preventing exercise-induced hypoglycemia is the most effective strategy for managing this condition. Athletes with T1DM, along with their coaches, teammates, and medical support team, must stay vigilant for early signs and symptoms of hypoglycemia, such as shakiness, confusion, or sweating. Prompt treatment involves consuming fast-acting carbohydrates, ideally glucose-based sources like glucose tablets or gels. In cases where an athlete is unconscious or unable to consume food or drink orally, an emergency glucagon injection is necessary to rapidly restore blood glucose levels. (20)

Research indicates that youths with T1DM typically exhibit approximately 20% lower aerobic capacity compared to their non-diabetic peers. However, physically active individuals with well-managed T1DM can often achieve aerobic capacities within the normal range for their age group. This discrepancy is attributed to several physiological impairments in T1DM, including cardiovascular, metabolic, and muscular limitations that reduce both aerobic and anaerobic performance. (21, 22)

For instance, a study by Rissanen et al. (2019) found that physically active adults with T1DM demonstrate a diminished cardiovascular response during peak exercise, characterized by reduced stroke volume, systemic vascular resistance, maximal oxygen uptake (VO2 max), and blood flow. These findings suggest both central (heart-related) and peripheral (muscle and vascular) limitations in individuals with T1DM compared to those without diabetes. Conversely, some studies involving highly active T1DM adults, such as long-distance runners, report no significant differences in aerobic capacity compared to non-diabetic counterparts, indicating that consistent physical activity and good glycemic control may mitigate these deficits. It remains unclear whether the reduced aerobic capacity in T1DM stems primarily from impaired muscle oxygenation or a reduced density of muscle capillaries, warranting further research to clarify these mechanisms. (23)

In contrast to aerobic exercise, anaerobic activities—such as sprinting, short-distance races, or team sports—tend to have minimal impact on blood glucose levels in individuals with T1DM. When changes do occur, they often manifest as elevated blood glucose levels, driven by a surge in catecholamines (stress hormones like adrenaline) and increased lactate production. These physiological responses during anaerobic exercise can suppress glucose and free fatty acid uptake by muscles while promoting hepatic glucose production, fuelled by lactate, which further elevates blood glucose levels. This complex interplay of hormones and metabolic by-products underscores the need for tailored glucose management strategies during different types of physical activity.

To expand on this, athletes with T1DM must adopt a proactive approach to glucose monitoring, particularly before, during, and after exercise. Continuous glucose monitoring (CGM) systems can provide real-time data to help anticipate and prevent hypoglycemic episodes. Additionally, individualized nutrition plans, including pre-exercise carbohydrate intake and post-exercise recovery meals, play a critical role in maintaining stable glucose levels. Collaboration with healthcare providers, such as endocrinologists and sports dieticians, can further optimize an athlete's ability to balance exercise demands with diabetes management, ensuring both safety and performance are maximized.

While most research on prescribing anaerobic exercises for T1DM patients indicates positive outcomes, such as reduced hypoglycemia during acute exercise, the risk may increase hours later. Further studies are needed to establish a scientific foundation for developing guidelines in this context.

For diabetic athletes engaging in regular exercise, 50-60% of their daily diet should consist of carbohydrates, timed with exercise and insulin dosage. This strategy is crucial for optimal glycemic control, preserving muscle mass, and maintaining liver and muscle glycogen stores, which enhances exercise performance, reduces fatigue, and helps prevent complications.

Strategies and Precautions for Physical Exercise and Insulin Use in T1DM Athletes

Insulin, illicitly used by some athletes (notably weightlifters and fighters), has been classified as a banned substance since 2005. Athletes with type 1 diabetes mellitus (T1DM) aiming to compete in national or international sports events under international anti-doping regulations must provide medical documentation from a physician confirming their diagnosis and treatment. Beyond routine capillary blood glucose monitoring for T1DM, glucose levels should be checked 1-2 hours before exercise and again just before starting to assess glucose trends and guide appropriate actions. If glucose levels trend downward (lower just before exercise compared to 2 hours prior), consuming carbohydrates can serve as a preventive measure. Conversely, if glucose levels trend upward (higher just before exercise), carbohydrate intake may not be necessary. (24)

Glucose levels should also be monitored immediately after exercise and 1-2 hours later. If levels are too low, carbohydrate consumption is recommended to mitigate the risk of hypoglycemia. For anaerobic exercises, which may cause hyperglycemia due to their intensity, insulin adjustments should be minimal or avoided altogether. Additionally, caution is needed as some athletes may use anabolic agents, which can induce or exacerbate hyperglycemia. (25)

Influence of Exercise on Insulin Types and Management in T1DM

Exercise can alter the absorption rates of both mealtime and basal insulin. For NPH insulin, absorption can double with elevated temperatures at the injection site, primarily due to increased subcutaneous blood flow. This enhanced blood flow accelerates the absorption of free insulin across all insulin types. However, with NPH insulin, it may also promote the dissociation of complex insulin, and with insulin glargine, it can affect microprecipitates. In contrast, insulin detemir experiences increased absorption of free insulin detemir during exercise, but its impact is mitigated because it binds to a large pool of albumin in circulation, reducing the risk of hypoglycemia post-exercise in individuals with well-controlled T1DM. (26)

Another key consideration is the type of insulin used. Lispro insulin, with its faster absorption compared to regular insulin, better manages early postprandial glucose spikes, thereby lowering the risk of late postprandial hypoglycemia.

For exercises performed at less than 70% of VO2 max and lasting under 30 minutes, minimal adjustments to insulin therapy are typically needed. However, a 30-50% reduction in rapid-acting insulin post-exercise has been shown to effectively decrease the risk of hypoglycemia. Additionally, reducing the total daily insulin dose by 10-30% can further support glycemic stability. (27, 28)

Individuals with T1DM engaging in moderate-intensity physical activity for 45 minutes in the afternoon or early evening face a 30-40% increased risk of nocturnal hypoglycemia. This is particularly concerning as hypoglycemia during sleep may go unnoticed. To mitigate this risk, a 20-50% reduction in basal insulin dose or consuming a snack containing complex carbohydrates and proteins is recommended. (29)

2.Conclusion

In conclusion, numerous neuroendocrine disorders can significantly impact blood glucose regulation during physical activity, posing unique challenges for healthcare professionals managing patients with type 1 diabetes mellitus (T1DM). Research highlights that aerobic exercises typically lead to reductions in blood glucose levels, while anaerobic exercises may cause temporary hyperglycemia. Despite these complexities, individuals with T1DM can excel in sports by implementing meticulous blood glucose monitoring, tailored insulin adjustments on exercise days, and optimized nutritional strategies. These measures are essential not only for enhancing athletic performance but also for ensuring safety and preventing glycemic complications. The consistent engagement in physical activity fosters substantial improvements in physical fitness, which in turn enhances overall health, well-being, and quality of life for T1DM patients. Moreover, regular exercise supports better glycemic control, cardiovascular health, and mental resilience, underscoring its critical role in the comprehensive management of T1DM and reinforcing the importance of personalized exercise prescriptions in this population.

References

[1] Anaruma CP, Ferreira Jr M, Sponton CHG, Delbin MA, Zanesco A. Heart rate variability and plasma biomarkers in patients with type 1diabetes mellitus: Effect of a bout of aerobic exercise. Diabetes Res Clin Pract.2016; 111: 19-27
[2] American Diabetes Association. Position Statement: Physical Activity/Exercise and Diabetes. Diabetes Care.2004; 27 (Suppl 1): S58-S62.
[3] American Diabetes Association. Foundations of Care: Education, nutrition, physical activity, smoking cessation, psychosocial care, and immunization. Diabetes Care.2015; 38 (Suppl 1): S20-30.
[4] Arutchelvam V, Heise T, Dellweg S, Elbroendt B, Minnst I, Home PD. Plasma glucose and hypoglycaemia following exercise in people with type 1 diabetes: a comparison of three basal insulins. Diabet Med, 2009; 26 (10): 1027-1032.
[5] Riddell, M. C., Gallen, I. W., Smart, C. E., Taplin, C. E., Adolfsson, P., Lumb, A. N., . . . & Annan, F. (2017). Exercise management in type 1 diabetes: A consensus statement. The Lancet Diabetes & Endocrinology, 5 (5), 377-390. https://doi. org/10.1016/S2213-8587 (17) 30014-1
[6] Yardley, J. E., Kenny, G. P., Perkins, B. A., Riddell, M. C., Malcolm, J., Boulay, P., . . . & Sigal, R. J. (2013). Effects of performing resistance exercise before versus after aerobic exercise on glycemia in type 1 diabetes. Diabetes Care, 36 (4), 669-675. https://doi. org/10.2337/dc12-0963
[7] Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., . . . & Tate, D. F. (2016). Physical activity/exercise and diabetes: A position statement of the American Diabetes Association. Diabetes Care, 39 (11), 2065-2079. https://doi. org/10.2337/dc16-1728
[8] Cryer PE. Iatrogenic hypoglycemia as a cause of hypoglycemia associated autonomic failure in IDDM. Diabetes.1992; 41 (3): 255-260.
[9] Davis SN, Tate D. Effects of morning hypoglycemia on neuroendocrine and metabolic responses on subsequent afternoon hypoglycemia in normal man. J. Clin. Endocrinol. Metab.2001; 86 (5): 2043-2050.
[10] Davis SN, Shavers C, Mosqueda-Garcia R, Costa F. Effects of differing antecedent hypoglycemia on subsequente counterregulation in normal humans. Diabetes.1997; 46 (8): 1328-35
[11] Gardim CB, Oliveira BAP, Bernardo AFB, Gomes RL, Pacagneli FL, Lorençoni RM, Valderlei LCM. Heart rate variability in children with type 1 diabetes mellitus. Rev Paul Pediatr.2014; 32 (2): 279-85.
[12] Guelfi KJ, Jones TW, Fournier PA. Intermittent high-intensity exercise does not increase the risk of early postexercise hypoglycaemia in individuals with type 1 diabetes. Diabetes Care.2005; 28 (2): 416-417.
[13] Harmer AR, Chisholm DJ, McKenna MJ, Morris NR, Thom JM, Bennett G, Flack JR. High-intensity training improves plasma glucose and acid-base regulation during intermittent maximal exercise in type 1 diabetes. Diabetes Care.2007; 30 (5): 1269 - 1271.
[14] Golbidi S, Badran M, Laher I. Antioxidant and anti-inflammatory effects of exercise in diabetic patients. J Diabetes Res.2012; 1-16.
[15] Ivy JL, Katz AL, Cutler CL. Muscle glycogen synthesis after exercise: effect of time of carbohydrate ingestion. J Appl Physiol.1988; 64: 480-485.
[16] Jenni S, Oetliker C, Allemann S. Fuel metabolismo during exercise in euglycaemia and hyperglycaemia in patients with Type 1 diabetes mellitus-a prospective single-blinded randomised crossover trial. Diabetologia.2008; 51 (8): 1457-1465.
[17] Jeukendrup AE, Achten J. Fatmax: A new concept to optimize fat oxidation during exercise? European Journal of Sport Science.2001; 1 (5): 1-5.
[18] Jimenez CC, Corcoran MH. National athletic trainers' association position statement: management of the athlete with type 1 diabetes mellitus. J Athl Training.2007; 42 (4): 536-545.
[19] Kivela R, Silvennoinen M, Touvra AM, Lehti TM, Kainulainen H, Vihko V. Effects of experimental type 1 diabetes and exercise training on angiogenic gene expression. and capillarization in skeletal muscle. FASEB J.2006; 20 (9): 1570-2.

[20] Lee AD, Hansen PA, Schluter J, Gulve EA, Gao J, Holloszy JO. Effects of epinephrine on insulin-stimulated glucose uptake and GLUT-4 phosphorylation in muscle. Am J Physiol.1997; 273 (3): C1082-7.
[21] Lima VA, Leite N, Titski ACK, Souza WC, Mascarenhas LPM. Comparison of acute of aerobic and flashing continuous training in effect of diabetes patients with type 1 blood glucose. Revista Pesquisa em Fisioterapia.2015; 5 (2): 102-107.
[22] Macknight JM, Mistry DJ, Pastors JG, Holmes V, Rynders CA. The daily management of athletes with diabetes. Clin. Sports Med.2009; 28 (3): 479-95
[23] Maughan RJ. Impact of mild dehydration on wellness and on exercise performance. Eur J Clin Nutr.2003; 57 (Suppl 2): S19-S23.
[24] Tsalikian E, Mauras N, Beck RW, Tamborlane WV, Janz KF, Chase HP. Impact of exercise on overnight glycemic control in children with type 1 diabetes mellitus. J Pediatr.2005; 147 (4): 528-34.
[25] Veves A, Saouaf R, Donaghue VM, Mullooly CA, Kistler JA, Giurini JM. Aerobic exercise capacity remains normal despite impaired endothelial function in the micro - and macrocirculation of physically active IDDM patients. Diabetes.1997; 46 (11): 1846-52.
[26] Wasserman DH. Four grams of glucose. Am J Physiol Endocrinol Metab.2009; 296: E11-E21.
[27] Shilo S, Sotsky M, Shamoon H. Islet hormonal regulation of glucose turnover during exercise in Type 1 diabetes. J. Clin. Endocrinol. Metab.1990; 70 (1): 162-172.
[28] Veves A, Saouaf R, Donaghue VM, Mullooly CA, Kistler JA, Giurini JM. Aerobic exercise capacity remains normal despite impaired endothelial function in the micro - and macrocirculation of physically active IDDM patients. Diabetes.1997; 46 (11): 1846-52.
[29] Yardle JE, Kenny GP Perkins BA, Riddell MC, Balaa N. et al Resistance versus aerobic exercise. Diabetes Care.2013; 36: 537-542